(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 803 966 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
06.07.2016 Bulletin 2016/27

(51) Int Cl.:
G01L 23/22 *(2006.01)* ***F02D 41/00*** *(2006.01)*
F02P 5/152 *(2006.01)* ***F02D 35/02*** *(2006.01)*
G01M 15/04 *(2006.01)* ***G01M 15/11*** *(2006.01)*

(21) Application number: **14168371.4**

(22) Date of filing: **14.05.2014**

(54) Method for detecting detonation phenomena in an internal combustion engine

Verfahren zur Erkennung des Klopfvorgangs in einer Brennkraftmaschine

Procédé de détection de phénomènes de détonation dans un moteur à combustion interne

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **14.05.2013 IT BO20130224**

(43) Date of publication of application:
19.11.2014 Bulletin 2014/47

(73) Proprietor: **Magneti Marelli S.p.A.
Corbetta (MI) (IT)**

(72) Inventors:
- **Garagnani, Nicola
40056 CRESPELLANO (IT)**
- **Lanzoni, Riccardo
40026 IMOLA (IT)**
- **Cavanna, Filippo
40139 BOLOGNA (IT)**

(74) Representative: **Maccagnan, Matteo et al
Studio Torta S.p.A.
Via Viotti, 9
10121 Torino (IT)**

(56) References cited:
US-A- 5 386 722 US-B1- 6 234 146

EP 2 803 966 B1

Description

TECHNICAL FIELD

[0001] The present invention relates to method for detecting detonation phenomena in an internal combustion engine.

PRIOR ART

[0002] A spark ignited, internal combustion engine comprises a number of cylinders, each of which is provided with a piston, which cyclically slides within the cylinder, and with a spark plug, which is cyclically operated by an electronic control unit to generate a spark between its electrodes, and thus determine the ignition of the compressed gases within the cylinder itself. The control unit comprises a memory, in which there is stored a series of maps which provide the operating values of the spark plugs as a function of the current engine point; in particular, the maps provide the value of the spark advance, i.e. the value of the angular interval existing between the ignition, i.e. the generation of the spark between the electrodes of the spark plug, and the top dead center or TDC of the piston, for each spark plug; if the value of the spark advance is zero, then the ignition, i.e. the generation of the spark between the electrodes of the spark plug, occurs exactly at the top dead center or TDC of the piston.

[0003] The values of the spark advance stored in the maps contained in the control unit are determined during the engine set up phase to attempt to ensure a good combustion under all possible conditions of operation, obtain a good thermal efficiency of the engine while safeguarding the integrity of the engine itself, i.e. avoiding the presence of excessive detonation phenomena in the cylinders. Detonation is an explosive type combustion of part of the air-fuel mixture, which occurs before the mixture is reached by the flame front generated by the spark plug; a series of pressure waves, which cross the combustion chamber and violently impact against the metal walls, are created upon the detonation. Detonation occurs when given critical temperature and pressure values are exceeded inside the chamber (which may vary even considerably from engine to engine) and which, when occurring at medium-to-low rpm, often cause a typical, clearly perceivable metallic noise known as "knocking" or "pinging".

[0004] Detonation normally occurs when spark advance is excessive, when a fuel with an excessively low octane rating is used (the antiknock potential of a fuel is indeed indicated by its octane rating) or, for supercharged engines, when the supercharging pressure is too high.

[0005] The combustion trend is influenced by many factors (the most important are the fuel features, the engine head temperature, the spark plug decay), the effect of which is substantially impossible to predict with accuracy. For this reason, the absence of excessive detonation must be detected and, in the case of excessive detonation in a cylinder, the control unit must reduce the value of the spark advance for such a cylinder so as to eliminate the detonation in the cylinder itself (so the maximum pressure reached in the cylinder is reduced and reached later with respect to TDC, making the detonation event "less likely").

[0006] However, in terms of combustion efficiency, reducing the spark advance of a cylinder corresponds to a loss of thermodynamic efficiency: the air mass for the cylinder, and thus the injected gasoline mass, are maintained constant but by reducing the spark advance, the combustion efficiency, i.e. the fraction of chemical energy which is converted into mechanical energy, is reduced. Obviously, this has negative repercussions on fuel consumption and on the generation of polluting substances.

[0007] For this reason, having a strategy which allows to effectively recognize the development of excessive detonation is crucial. Prior art methods for determining these phenomena are disclosed in, for example, US5386772A.

DESCRIPTION OF THE INVENTION

[0008] It is the object of the present invention to provide a method for detecting detonation phenomena in an internal combustion engine, such a control method being free from the above-described drawbacks, and in particular, being easy and cost-effective to be implemented.

[0009] It is the further object of the present invention to provide an electronic control unit suited to recognize detonation phenomena in an internal combustion engine which is free from the drawbacks of the prior art.

[0010] According to the present invention, a control unit and a method for detecting detonation phenomena in an internal combustion engine are provided as claimed in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The present invention will now be described with reference to the accompanying drawings, which show a non-limitative embodiment thereof, in which:

- figure 1 is a diagrammatic view of an internal combustion engine provided with a control unit which implements the method for detecting detonation phenomena of the present invention;
- figure 2 is a diagrammatic view of a cylinder of the internal combustion engine in figure 1; and
- figure 3 is a block chart of the method for detecting detonation phenomena of the present invention.

PREFERRED EMBODIMENTS OF THE INVENTION

[0012] In figure 1, reference numeral 1 indicates as a whole a spark ignited internal combustion engine comprising four cylinders 2 in a straight arrangement. Each cylinder 2 comprises a respective piston 3 which is mechanically connected by means of a connecting rod to a drive shaft 4 to transmit the force generated by the combustion in cylinder 2 to the drive shaft 4 itself.

[0013] As shown in figure 2, the internal combustion engine 1 comprises an intake manifold 5, which is connected to each cylinder 2 by means of two intake valves 6 (of which only one is shown in figure 2) and receives fresh air (i.e. air from the outside environment) though a butterfly valve 7 which is moveable between a closing position and a maximum opening position. Furthermore, the internal combustion engine 1 comprises an exhaust manifold 8, which is connected to each cylinder 2 by means of two exhaust valves 9 (only one of which is shown in figure 2) which flows into an emission pipe (not shown) to emit the gases produced in the combustion into the atmosphere.

[0014] The position of each exhaust valve 9 is directly controlled by a camshaft 10 which receives motion from the drive shaft 4; instead, the position of the intake valves 6 is controlled by a valve opening controlling device 11 which controls the intake valves 6 by managing the opening angle and lift so as to control the delivered torque by means of the intake valves 6. The valve opening control device 11 uses a traditional camshaft 12 which receives motion from the drive shaft 4 and for each intake valve 6 comprises an electrically controlled hydraulic actuator 13 (i.e. controlled by means of a solenoid valve), which is interposed between a stem of the intake valve 6 and the camshaft 12. By appropriately controlling each hydraulic actuator 13, it is possible to adjust the motion transmitted by the camshaft 12 to the intake valve stem 6, and it is thus possible to adjust the actual lift of the intake valve 6. Thus, the action of the control device 11 allows to vary the actual lift of each intake valve 6 independently from the other intake valves 6, for each cylinder 2 and engine cycle.

[0015] A corresponding injector 14 is provided for each cylinder 2; according to the embodiment shown in figure 2, the injector is of the indirect type and thus each injector 14 is arranged upstream of a cylinder 2 in an intake pipe which connects the intake manifold 5 to cylinder 2. According to an alternative embodiment (not shown), the injector is of the direct type and thus each injector 14 is partially arranged within cylinder 2.

[0016] Furthermore, each cylinder 2 comprises a spark plug 15, which is arranged through the top of cylinder 2 in central position between the intake valves 5 and the exhaust valves 9 and is cyclically activated to determine the ignition of the compressed gases within cylinder 2 at the end of each compression stroke.

[0017] Engine 1 comprises a control unit 16, which governs the operation of the internal combustion engine 1 and also controls the spark plugs 15 to determine the ignition of the compressed gases in each cylinder 2. The control unit 16 comprises a memory 17 in which a series of maps which provide the operating values of the spark plugs 15 as a function of the current engine point are stored; in particular, the maps stored in the memory 17 provide a standard spark advance for each spark plug 15 (i.e. for each cylinder 2).

[0018] The method for controlling the detonation in the internal combustion engine 1 which is implemented by the control unit 16 is described below.

[0019] The method for detonation control method which is implemented by the control unit 16 includes providing an indication of the intensity of the detonation phenomenon in the internal combustion engine 1 by appropriating processing a signal coming from one or more detonation sensors connected to the control unit 16. For example, a detonation sensor arranged to determine the ignition of the compressed gases within each cylinder 2 is provided for each spark plug 15.

[0020] According to a preferred variant, each detonation sensor comprises a voltage gauge which is connected and arranged in series to the electric circuit of the spark plug 15 to measure the voltage at the terminals of the electrodes of the spark plug 15 during combustion.

[0021] According to a further variant, each detonation sensor comprises a pressure gauge which measures the maximum amplitude pressure oscillation (MAPO) of the intensity of the pressure waves generated in the cylinders 2 of the internal combustion engine 1 during combustion.

[0022] According to a further variant, detonation sensors comprise an accelerometer, which is preferably connected to a motor housing of the internal combustion engine 1.

[0023] Figure 3 diagrammatically shows the detonation control method which is implemented by the control unit 16, in which block 20 receives in input the signal or signals coming from said one or more detonation sensors connected to the control unit 16 and each comprising a respective voltage gauge; block 20 processes the signal or signals coming from said one or more detonation sensors connected to the control unit 16 and then outputs the processed signal to the following block 30.

[0024] In particular, the signal or signals coming from said one or more detonation sensors connected to the control unit 16 is or are sampled at a constant frequency determined during a preliminary adjustment and set up phase. According to a preferred variant, such a sampling frequency is equal to 50 kHz. According to a preferred variant, when at least two detonation sensors are provided, the sampling frequency assumes the same value for all the detonation sensors. Once the signal coming from said one or more detonation sensors connected to the control unit 16 has been sampled, an alternating signal which is then rectified is obtained. The rectified signal is further processed to be transmitted to block 30.

[0025] According to a first variant, the derivative is calculated from the rectified signal and thus transmitted block 30. The derivative action of the rectified signal has the drawback of making the detonation control method which is implemented by the control unit 16 excessively sensitive to variations of the signal itself.

[0026] According to a second preferred variant, the integral is calculated from the rectified signal and thus transmitted to block 30. The integral action on the rectified signal allows the detonation control method implemented by the control unit 16 to store the passed values of the signal. As shown in figure 3, the integrated signal is then transmitted to block 30.

[0027] It is equally worth emphasizing that the integrated signal which is transmitted to block 30 simply represents the combustion energy. Such a combustion energy clearly depends on cylinder 2 and on the engine point in which the combustion is being observed because the signal comes from a detonation sensor, which is connected to the electric circuit of a respective spark plug 15 to measure the voltage at the terminals of the electrodes of the spark plug 15 itself during combustion in a given engine point of the respective cylinder 2.

[0028] It has been empirically found that the detonation energy of each combustion taken into account (i.e. for the cylinder 2 taken into account in a given engine point) is variable between a zero value, which indicates complete absence of detonation, and a maximum value, which indicates a completely detonating combustion. In particular, the detonation energy of each combustion taken into account (i.e. for the cylinder 2 taken into account in a given engine point) assumes a log-normal distribution χ^2. Such a log-normal distribution χ^2 may be distorted by means of a mathematical device (i.e. by applying a logarithmic curve) and is transformed into a Gaussian or normal distribution, characterized by a mean value μ_1 and a standard deviation σ_1.

[0029] Obviously, the log-normal distribution χ^2 is simply the probability distribution of an aleatory variable the logarithm of which follows a normal distribution characterized by a mean value μ_1 and by a standard deviation σ_1.

[0030] Block 30 is thus prepared to receive in input the log-normal distribution χ^2 of the detonation energy for each combustion taken into account (i.e. for the cylinder 2 taken into account in a given engine point) and process it so as to output the normal distribution of the detonation energy for each combustion taken into account (i.e. for the cylinder 2 taken into account in a given engine point).

[0031] The processing of block 30 of the log-normal distribution χ^2 of the detonation energy in each combustion taken into account (i.e. for the cylinder 2 taken into account in a given engine point) is calculated because the mean value μ_1 and the standard deviation σ_1 are independent in the normal distribution although they both depend on the engine point.

[0032] In particular, the normal distribution of the detonation energy of each combustion taken into account (i.e. for the cylinder 2 taken into account in a given engine point) is characterized by a mean value μ_i and by a standard deviation σ_i.

[0033] The mean value μ_i is the nominal noise contribution of the combustion taken into account (i.e. for the cylinder 2 taken into account in the current engine point). In other words, the mean value μ_i is the energy, i.e. the mean noise, of the combustion taken into account (i.e. for the cylinder 2 in the current engine point).

[0034] Standard deviation σ_i is determined instead by the cyclic variability, including incorrect combustion phenomena (misfire, detonation etc.). In other words, the deviation of the value of the i-th combustion from the mean value allows to identify the trend or predisposition to detonate of the combustion taken into account (i.e. for the cylinder 2 in the current engine point).

[0035] It is immediately apparent that correctly determining the mean value μ_i (i.e. the nominal noise contribution of the combustion taken into account, i.e. for the cylinder 2 taken into account in the current engine point) and the standard deviation σ_i (i.e. the trend or predisposition to detonate of the combustion taken into account, i.e. for the cylinder 2 taken into account in the current engine point) are at the heart of the method for controlling detonation in the internal combustion engine 1 which is implemented by the control unit 16.

[0036] Block 30 thus provides a representative value of the overall noise (mean nominal noise +/- noise due to specific combustion cycle phenomena which occurred for the cylinder 2 taken into account and in the current engine point, which are impossible to separate beforehand from the mean nominal noise). In other words, block 30 provides the overall combustion energy μ_i of the i-th combustion taken into account for the cylinder 2 taken into account in the current engine point.

[0037] The combustion energy μ_i of the i-th combustion taken into account for the cylinder 2 taken into account in the current engine point block 30 output from block 40 is transmitted and inputted into a block 40 which is suited to determine the average combustion energy μ_{i-m} for the cylinder 2 taken into account in the current engine point.

[0038] Block 40 is simply a filter, preferably of the low-pass type. According to a preferred variant, such filter is a first order filter. Also in this case, it is apparent that a correct determination of the constant k filter in block 40 is a fundamental aspect of the method for controlling the detonation in the internal combustion engine 1 which is implemented by the control unit 16. The constant k filter must indeed result from the trade-off between the need of independence of the single i-th combustion taken into account for the cylinder 2 taken into account in the current engine point and the capacity of the filter itself to react to changes of conditions, i.e. the capacity of the filter itself to adapt to variations of the cylinder 2 taken into account and current engine point (in yet other words, the filter must not be excessively "deaf" to variations of the cylinder 2 taken into account and current engine point).

[0039] A group of maps $MAPS_1$ are stored in the control unit 16. According to a preferred variant, the group of maps $MAPS_1$ comprises a map $MAPS_1$ for each cylinder 2 of the internal combustion engine 1. In turn, each map $MAPS_1$ for each cylinder 2 of the internal combustion engine 1 comprises a variable number of cells as a function of the engine points which may be explored during the running of the internal combustion engine 1. Each map $MAPS_1$ for each cylinder 2 of the internal combustion engine 1 comprises a number of cells univocally identified by the number of revolutions per minute (rpm) and the load.

[0040] The filtered value of the combustion energy μ_i of the i-th combustion taken into account for the cylinder 2 taken into account in the current engine point output from block 40 is used to update the corresponding cell in the group of maps $MAPS_1$; i.e. the filtered value is used to update the map $MAPS_1$ of the cylinder 2 taken into account in its i-th combustion in the current engine point defined by the number of revolutions per minute (rpm) and the load (load).

[0041] The updating of the cell in the group of maps $MAPS_1$ is obtained by means of a weighted mean between the value already stored in said cell in the group of maps $MAPS_1$ and the filtered value of the combustion energy μ_i in the i-th combustion taken into account for the cylinder 2 taken into account in the current engine point output from block 40.

[0042] The mean combustion energy μ_{i_m} for the cylinder 2 taken into account in the current engine point is thus obtained by means of the weighted mean of the value already stored in the cell in the group of maps $MAPS_1$ and the filtered value of the combustion energy μ_i in the i-th combustion taken into account and is made so that by updating the cell in the group of maps μ_i the filtered value of the combustion energy of the i-th combustion taken into account assumes a gradually decreasing value. In other words, the more i-th combustions in the cylinder 2 taken into account in the current engine point from which the combustion energy μ_i (i.e. its nominal noise) was derived, the more relevant will be the contribution of the filtered value of the combustion energy μ_i of the n-th combustion taken into account and the higher will be the contribution of the value already stored in the cell in the group of maps $MAPS_1$.

[0043] For this purpose, a group of maps $MAPS_2$ are also stored in the control unit 16. According to a preferred variant, the structure of the group of maps $MAPS_2$ is identical to the structure of the group of maps $MAPS_1$.

[0044] In other words, according to a preferred variant, the group of maps $MAPS_2$ comprises a map $MAPS_2$ for each cylinder 2 of the internal combustion engine 1; i.e. a respective map $MAPS_1$ of the group of maps $MAPS_1$ is associated to each map $MAPS_2$. Furthermore, in turn, each map $MAPS_2$ for each cylinder 2 of the internal combustion engine 1 comprises a variable number of cells as a function of the engine points which may be explored during the running of the internal combustion engine 1. Each map $MAPS_2$ for each cylinder 2 of the internal combustion engine 1 comprises a number of cells univocally identified by the number of revolutions per minute (rpm) and the load (load). Also in this case, each cell which identifies an engine point in the maps $MAPS_2$ thus corresponds to a respective cell which identifies the same engine point in the $MAPS_1$.

[0045] The group of maps $MAPS_2$ comprises counters of the number of combustions taken into account during the life of the internal combustion engine 1 for the corresponding cylinder 2 and in a given engine point in the cells.

[0046] The counters in the cells of the group of maps $MAPS_2$ are initialized in a preliminary adjustment and set up phase of the control unit 16. According to a preferred embodiment, the initialization values of the counters in the cells of the group of maps $MAPS_2$ are variable as a function of the cylinder 2 and/or engine point taken into account.

[0047] Furthermore, a lower saturation value is also determined during a preliminary adjustment and set up phase. According to a preferred embodiment, the lower saturation value is variable as a function of the cylinder 2 and/or engine point taken into account.

[0048] In use, when a combustion is observed during the life of the internal combustion engine 1 for a given cylinder 2 and in a given engine point, the corresponding counter of the cell of the group of maps $MAPS_2$ which corresponds to that given cylinder 2 and that given engine point is decreased by one unit.

[0049] As the number of combustions observed during the life of the internal combustion engine 1 for a given cylinder 2 and in a given engine point (i.e. as the counter in the cell of the group of maps $MAPS_2$ which corresponds to that given cylinder 2 and that given engine point decreases) the weight of the value already stored in the cell in the group of maps $MAPS_1$ increases and therefore the weight of the filtered value of the combustion energy μ_i of the i-th combustion taken into account is reduced.

[0050] In the weighted mean between the value already stored in the cell in the group of maps $MAPS_1$ and the filtered value of the combustion energy μ_i of the i-th combustion taken into account, the values of the weights are thus variable during the life of the internal combustion engine 1, in particular as a function of the counter in the cell of the group of maps $MAPS_2$ which corresponds to that given cylinder 2 and that given engine point.

[0051] According to a first variant, since the corresponding counter in the cell of the group of maps $MAPS_2$ which corresponds to a given cylinder 2 and to a given engine point is decreased by one unit for a given cylinder 2 and a given engine point when a combustion is observed during the life of the internal combustion engine 1, the condition may be reached in which the counter is zero and so the filtered value of the combustion energy μ_i of the i-th combustion taken into account is no longer taken into consideration; in other words, the mean combustion energy μ_i of the i-th combustion taken into account for the cylinder 2 taken into account in the current engine point is equal to the value already stored in the cell in the group of maps $MAPS_1$.

[0052] According to a second preferred variant, the corresponding counter in the cell of the group of maps $MAPS_2$ which corresponds to that given cylinder 2 and to that given engine point is decreased by one unit until the corresponding lower saturation value is reached when a combustion is observed during the life of the internal combustion engine 1 for a given cylinder 2 and in a given engine point. Once the counter has reached the corresponding lower saturation value it is no longer decreased but maintained constant at the lower saturation value. Thereby, it is not possible to reach the condition in which the filtered value of the combustion energy μ_i of the i-th combustion taken into account is not considered. And thereby, the mean combustion μ_i of the i-th combustion taken into account for the cylinder 2 taken into account in the current engine point will continue to be equal to the weighted mean between the value already stored in the cell in the group of maps $MAPS_1$ and the filtered value of the combustion energy μ_i of the i-th combustion taken into account; wherein the value already stored in the cell in the group of maps $MAPS_1$ will have a predominant weight and the filtered value of the combustion energy μ_i of the i-th combustion taken into account will have a reduced weight.

[0053] Block 40 thus outputs the mean combustion energy μ_{i_m} for the cylinder 2 taken into account in the current engine point which is transmitted and inputted to a block 50. Block 50 thus receives in input both the mean combustion energy μ_{i_m} for the cylinder 2 taken into account in the current engine point block 40 and the combustion energy μ_i of the i-th combustion taken into account for the cylinder 2 taken into account in the current engine point by block 30. Block 50 is further suited to compare the mean combustion energy value μ_{i_m} for the cylinder 2 taken into account in the current engine point with the combustion energy μ_i of the i-th combustion taken into account for the cylinder 2 taken into account in the current engine point.

[0054] Thereby, block 50 can establish by how much the combustion energy μ_i of the i-th combustion taken into account for the cylinder 2 taken into account in the current engine point differs from the mean combustion energy μ_{i_m} for the cylinder 2 taken into account in the current engine point. Block 50 thus determines the deviation of the i-th combustion taken into account for the cylinder 2 taken into account in the current engine point, which represents the cyclic variability, i.e. the tendency or predisposition to detonate of the i-th combustion taken into account for the cylinder 2 taken into account in the current engine point.

[0055] Block 50 thus outputs the deviation of the i-th combustion taken into account for the cylinder 2 taken into account in the current engine point which is transmitted and inputted into a block 60. Block 60 receives in input both the deviation of the i-th combustion taken into account for the cylinder 2 taken into account in the current engine point from block 50 and the maximum tolerable deviation for the cylinder 2 taken into account in the current engine point.

[0056] Furthermore, block 60 is suited to compare the deviation of the i-th combustion taken into account for the cylinder 2 taken into account in the current engine point with the maximum deviation for the cylinder 2 taken into account in the current engine point.

[0057] The method for determining the maximum standard deviation σ_{i_MAX} for each cylinder 2 for each engine point explored during the operation of the internal combustion engine 1 is described below.

[0058] The control unit 16 is suited to implement an "intrusive" strategy for controlling the spark advance according to which the standard spark provided by the engine control by means of the maps 17 for each cylinder 2 in each engine point is degraded to be placed into the conditions in which the generation of detonation phenomena will not occur. Typically, such an "intrusive" strategy thus includes reducing the actuated spark advance until it is placed in the conditions in which certainly no detonation phenomena will occur for each cylinder 2 in each engine point.

[0059] A group of maps $MAPS_3$ are stored in the control unit 16. According to a preferred variant, the group of maps $MAPS_3$ comprises a map $MAPS_3$ for each cylinder 2 of the internal combustion engine 1. In turn, each map $MAPS_3$ for each cylinder 2 of the internal combustion engine 1 comprises a variable number of cells as a function of the engine points which may be explored during running of the internal combustion engine 1. Each map MAPS3 for each cylinder 2 of the internal combustion engine 1 comprises a number of cells univocally identified by the number of revolutions per minute (rpm) and the load).

[0060] A group of maps $MAPS_4$ are also stored in the control unit 16. According to a preferred variant, the structure of the group of maps $MAPS_4$ is identical to the structure of the group of maps $MAPS_3$.

[0061] In other words, according to a preferred variant, the group of maps $MAPS_4$ comprises a map $MAPS_4$ for each cylinder 2 of the internal combustion engine 1; i.e. a respective map $MAPS_3$ of the group of maps $MAPS_3$ is associated to each map $MAPS_4$. Furthermore, in turn, each map $MAPS_4$ for each cylinder 2 of the internal combustion engine 1 comprises a variable number of cells as a function of the engine points which may be explored during running of the internal combustion engine 1. Each map $MAPS_4$ for each cylinder 2 of the internal combustion engine 1 comprises a number of cells univocally identified by the number of revolutions per minute (rpm) and the load (load). Also in this case, each cell which identifies an engine point in the maps $MAPS_4$ corresponds to a respective cell which identifies the same engine point in the $MAPS_3$.

[0062] The group of maps $MAPS_4$ comprises in the cells counters of the number of combustions taken into account during the life of the internal combustion engine 1 for the corresponding cylinder 2 and in a given engine point.

[0063] The counters in the cells of the group of maps $MAPS_4$ are initialized in a preliminary adjustment and set up phase of the control unit 16. According to a preferred embodiment, the initialization values of the counters in the cells of the group of maps $MAPS_4$ are variable as a function of the cylinder 2 and/or the engine point taken into account. In use, when a combustion is observed during the life of the internal combustion engine 1 for a given cylinder 2 and in a given engine point, the corresponding counter in the cell in the group of maps $MAPS_4$ which corresponds to that given cylinder 2 and that given engine point is decreased by one unit.

[0064] Because the control unit 16 is suited to actuate a spark advance for each cylinder 2 in each engine point in order to avoid the generation of detonation phenomena, a number of combustions can be observed for the cylinder 2 taken into account in the current engine point equal to the corresponding counter in the cell of the group of maps $MAPS_4$ which corresponds to that given cylinder 2 and that given engine point in which detonation phenomena will certainly not occur.

[0065] For each i-th combustion taken into account for the cylinder 2 taken into account in the current engine point it is possible to analyze the signal of the i-th combustion itself taken into account and, in particular, it is possible to learn the nominal value of the noise peak of the i-th combustion taken into account for the cylinder 2 taken into account in the current engine point (with respect to the previous ones, from the starting instant of the learning procedure) to determine the maximum standard deviation σ_{i_MAX} for the cylinder 2 taken into account in the current engine point.

[0066] The nominal value of the noise peak of the i-th combustion taken into account for the cylinder 2 taken into account in the current engine point is used to update the corresponding cell in the group of maps $MAPS_3$; i.e. the nominal value of the noise peak of the i-th combustion taken into account for the cylinder 2 taken into account in the current engine point is used to update the map $MAPS_3$ of the cylinder 2 taken into account in the current engine point defined by the number of revolutions per minute (rpm) and by the load (load).

[0067] The updating of the cell in the group of maps MAPS3 is obtained by means of a weighted mean between the value already stored in the said cell in the group of maps $MAPS_3$ and the nominal value of the noise peak value of the i-th combustion taken into account for the cylinder 2 taken into account in the current engine point.

[0068] The weighted mean between the value already stored in the cell in the group of maps $MAPS_3$ and the nominal value of the noise peak of the i-th combustion taken into account for the cylinder 2 taken into account in the current engine point (with respect to the previous ones, from the starting instant of the learning procedure) is made so that the nominal value of the noise peak of the i-th combustion taken into account for the cylinder 2 taken into account in the current engine point has a gradually increasing weight. In other words, the more i-th combustions of the cylinder 2 taken into account in the current engine point in which the combustion energy μ_i (i.e. its nominal noise) can be observed, the more relevant will be the contribution of the nominal value of the noise peak of the i-th combustion taken into account for the cylinder 2 taken into account in the current engine point and the more relevant will be the contribution of the value already stored in the respective cell of the group of maps $MAPS_3$.

[0069] As the number of combustions observed during the life internal combustion engine 1 for given cylinder 2 and given engine point (i.e. as the counter in the cell of the group of maps $MAPS_4$ which corresponds to that given cylinder 2 and that given engine point) decreases, the weight of the nominal value of the noise peak of the i-th combustion taken into account for the cylinder 2 taken into account in the current engine point increases.

[0070] In the weighted mean of the value already stored in the cell in the group of maps $MAPS_3$ and the nominal value of the noise peak of the i-th combustion taken into account for the cylinder 2 in the current engine point, the values of the weights are thus variable during the step of learning of the internal combustion engine 1, in particular as a function of the counter in the cell of the group of maps $MAPS_4$ which corresponds to that given cylinder 2 and that given engine point.

[0071] According to a first variant, since the corresponding counter in the cell of the group of maps $MAPS_4$ which corresponds to a given cylinder 2 and to a given engine point is decreased by one unit when a combustion is observed during the life of the internal combustion engine 1 for that given cylinder 2 and that given engine point, the condition is reached in which the counter is zero and the learning phase may be said to be concluded.

[0072] However, since reducing the spark advance in a cylinder 2 corresponds to a loss of thermodynamic efficiency in terms of combustion efficiency as the air mass for cylinder 2, and thus the injected gasoline mass as well, are maintained constant, but the fraction of chemical energy converted into mechanical energy is reduced and because the learning phase for each cylinder is rather long, according to a preferred variant the learning step is carried out on one cylinder at a time to avoid negative repercussions on fuel consumption and on the generation of polluting substances.

[0073] Block 60 thus receives in input both the standard deviation σ_i of the i-th combustion taken into account for the cylinder 2 taken into account in the current engine point from block 50 and the maximum standard deviation σ_{i_MAX} for the cylinder 2 taken into account in the current engine point. Furthermore, block 60 is provided to compare the standard deviation σ_i of the i-th combustion taken into account for the cylinder 2 taken into account in the current engine point with the maximum standard deviation σ_{i_MAx} for the cylinder 2 taken into account in the current engine point. Furthermore, block 60 is suited to determine the development of detonation phenomena as a function of the comparison of the standard deviation σ_i of the i-th combustion taken into account for the cylinder 2 taken into account in the current engine point (which also represents the tendency to detonate of the i-th combustion taken into account for the cylinder 2 taken into account in the current engine point) with the maximum standard deviation σ_{i_MAX} for the cylinder 2 taken into account in the current engine point.

[0074] In the description above, the size of the maps indicated by $MAPS_1$, $MAPS_2$, $MAPS_3$ and $MAPS_4$ respectively depend on the number of cylinders (ncyl) and from the engine point, i.e. on the number of revolutions per minute (rpm) and the load (load).

[0075] Furthermore, according to a first variant, the control unit 16 is suited to re-initialize the groups of maps indicated by $MAPS_1$, $MAPS_2$, $MAPS_3$ and $MAPS_4$ respectively at the ignition events of the control unit 16.

[0076] According to a possible variant, the counters in the cells of the group of maps MAP_2 and of the group of maps $MAPS_4$ are initialized in a preliminary adjustment and set up phase of the control unit 16 to zero values. Furthermore, the upper saturation values are determined in a preliminary adjustment and set up phase. According to a preferred embodiment, the upper saturation values are variable as a function of the cylinder 2 and/or the engine point taken into account. In use, the corresponding counter in the respective cell of a group of maps $MAPS_2$ and in the respective cell of the group of maps $MAPS_4$ which corresponds to a given cylinder 2 and that a engine point is increased by one unit until the upper saturation value is reached when a combustion is observed during the life of the internal combustion engine 1 for that given cylinder 2 and in that given engine point.

[0077] Il sopra descritto metodo di controllo della detonazione presenta numerosi vantaggi.

[0078] Firstly, the above-described control method is applied individually to each cylinder 2, so that the inevitable differences which exist between the various cylinders due to the effect of construction tolerances and of the temperature differences of the walls of the cylinders due to the different positions of cylinders 2 in the internal combustion engine 1 may be taken into consideration.

[0079] Secondly, the above-described control method is simple and cost-effective to implement in an electronic control unit of an internal combustion engine 1 because it does not require any physical modifications and employs a low calculation capacity of the control unit 6.

[0080] Furthermore, the above-described detonation control method allows to recognize the development of detonation phenomena effectively and keep the detonation in the various cylinders 2 under control without noticeable negative effects on combustion thermodynamic efficiency which is maintained close to the maximum possible values with evident benefits on consumptions and pollution containment.

Claims

1. A method for detecting the development of detonation phenomena in an internal combustion engine (1) provided with a number of cylinders (2), a control unit (16), and a number of detonation sensors connected to the control unit (16); wherein, detonation sensors comprise an accelerometer and/or a voltage gauge which is connected and arranged in series to the electric circuit of a spark plug (15) to measure the voltage at the terminals of the electrodes of the spark plug (15) during combustion and/or a pressure gauge which measures the maximum amplitude pressure oscillation (MAPO) of the intensity of the pressure waves generated in the cylinders (2) during combustion; the method comprises the steps of:

    acquiring the signal (S) coming from said number of detonation sensors connected to the control unit (16);
    processing the signal (S) coming from said number of detonation sensors connected to the control unit (16) so as to obtain the detonation energy (μ_i) of each combustion taken into account for a given cylinder (2) and in a given engine point;
    filtering the detonation energy (μ_i) of each combustion taken into account for a given cylinder (2) and in a given engine point;
    calculating the mean detonation energy (μ_{i_m}) for a given cylinder (2) and in a given engine point by means of the filtered value of the detonation energy (μ_i) of each combustion taken into account for a given cylinder (2) and in a given engine point;
    comparing the detonation energy (μ_i) of each combustion taken into account for a given cylinder (2) and in a given engine point with the mean detonation energy (μ_{i_m}) for a given cylinder (2) and in a given engine point;

    characterized in that the method additionally comprises the steps of :

    determining the variance (σ_i) of each combustion taken into account for a given cylinder (2) and in a given engine point as a function of the comparison between the detonation energy (μ_i) of each combustion taken into account for a given cylinder (2) and in a given engine point and the mean detonation energy (μ_{i_m}) for a given cylinder (2) and in a given engine point;
    calculating the maximum variance (σ_{i_max}) for a given cylinder (2) and in a given engine point by means of a reduction of the spark advance actuated in the given cylinder (2) ;
    comparing the maximum variance (σ_{i_max}) for a given cylinder (2) and in a given engine point with the variance (σ_i) of each combustion taken into account for a given cylinder (2) and in a given engine point; and
    determining the development of detonation phenomena for each combustion taken into account for a given cylinder (2) and in a given engine point as a function of the comparison between the maximum variance (σ_{i_max}) for a given cyl-

inder (2) and in a given engine point and the variance (σ_i) of each combustion taken into account for a given cylinder (2) and in a given engine point.

2. A method according to claim 1 and comprising the further steps of:

initializing, in a preliminary adjustment and set up phase, a first map ($MAPS_1$) with the values of the mean detonation energy (μ_{i_m}) for a given cylinder (2) and in a given engine point; and updating the first map ($MAPS_1$) with the filtered value of the detonation energy (μ_i) of each combustion taken into account for a given cylinder (2) and in a given engine point.

3. A method according to claim 2 and comprising the further step of updating the first map ($MAPS_1$) with the filtered value of the detonation energy (μ_i) of each combustion taken into account for a given cylinder (2) and in a given engine point by means of a weighted mean between the filtered value of the detonation energy (μ_i) of each combustion taken into account for a given cylinder (2) and in a given engine point and the value of the mean detonation energy (μ_{i_m}) for a given cylinder (2) and in a given engine point contained in the first map ($MAPS_1$).

4. A method according to claim 3 and comprising the further steps of:

initializing, in a preliminary adjustment and set up phase, a second map ($MAPS_2$) of counters of the combustions taken into account for a given cylinder (2) and in a given engine point; and determining the weights to be assigned to the filtered value of the detonation energy (μ_i) of each combustion taken into account for a given cylinder (2) and in a given engine point and to the value of the mean detonation energy (μ_{i_m}) for a given cylinder (2) and in a given engine point contained in the first map ($MAPS_1$) as a function of the second map ($MAPS_2$) of counters of the combustions taken into account for a given cylinder (2) and in a given engine point.

5. A method according to claim 4, wherein the filtered value of the detonation energy (μ_i) of each combustion taken into account for a given cylinder (2) has a gradually decreasing value.

6. A method according to any of the previous claims and comprising the further steps of:

initializing, in a preliminary adjustment and set up phase, a third map ($MAPS_3$) with the values of the maximum variance (σ_{i_max}) for a given cylinder (2) and in a given engine point; and updating, during a learning phase, the third map ($MAPS_3$) with the nominal value of the noise peak of the i-th combustion taken into account for a given cylinder (2) and in a given engine point.

7. A method according to claim 6 and comprising the further step of updating the third map ($MAPS_3$) with the nominal value of the noise peak of the i-th combustion taken into account for a given cylinder (2) and in a given engine point by means of a weighted mean between the nominal value of the noise peak of the i-th combustion taken into account for a given cylinder (2) and in a given engine point and the value of the maximum variance (σ_{i_max}) for a given cylinder (2) and in a given engine point contained in the third map ($MAPS_3$).

8. A method according to claim 7 and comprising the further steps of:

initializing, in a preliminary adjustment and set up phase, a fourth map ($MAPS_4$) of counters of the combustions taken into account for a given cylinder (2) and in a given engine point; and determining the weights to be assigned to the nominal value of the noise peak of the i-th combustion taken into account for a given cylinder (2) and in a given engine point and to the value of the maximum variance (σ_{i_max}) for a given cylinder (2) and in a given engine point contained in the third map ($MAPS_3$) as a function of the fourth map ($MAPS_4$) of counters of the combustions taken into account for a given cylinder (2) and in a given engine point.

9. A method according to claim 8, wherein the nominal value of the noise peak of the i-th combustion taken into account for a given cylinder (2) and in a given engine point has a gradually increasing value.

10. A method according to any of the claims from 2 to 9, wherein the first map ($MAPS_1$) and/or the second map ($MAPS_2$) and/or the third map ($MAPS_3$) and/or the fourth map ($MAPS_4$) have a number of cells that varies as a function of the number (N_{cyl}) of cylinders (2) and of the engine points identified by the number of revolutions per minute (rpm) and by the load (load).

11. A method according to any of the previous claims, wherein the step of calculating the maximum variance (σ_{i_max}) for a given cylinder (2) and in a given engine point by means of a reduction of the spark advance actuated in the given cylinder (2) is performed by degrading the spark advance actuated in the given cylinder (2) up to a value that is such that no detonation phenomena will occur.

12. An electronic control unit (16), which is suited to implement a method for detecting the development of detonation phenomena in an internal combustion engine (1) performed according to one or more of the claims from 1 to 11.

Patentansprüche

1. Verfahren zum Erkennen der Entwicklung eines Klopfvorgangs in einer Brennkraftmaschine (1), die mit einer Zahl von Zylindern (2), einer Steuerungseinheit (16) und einer Zahl von mit der Steuerungseinheit (16) verbundenen Klopfsensoren versehen ist; wobei Klopfsensoren einen Beschleunigungsmesser und/oder einen Spannungsmesser, der mit dem elektrischen Kreis einer Zündkerze (15) in Reihe geschaltet und angeordnet ist, um die Spannung an den Polen der Elektroden der Zündkerze (15) während der Verbrennung zu messen, und/oder einen Druckmesser aufweisen, der die Druckschwingung maximaler Amplitude (MAPO) der Intensität der in den Zylindern (2) während der Verbrennung erzeugten Druckwellen misst; wobei das Verfahren folgende Schritte beinhaltet:

Erfassen des Signals (S), das von der Zahl der mit der Steuerungseinheit (16) verbundenen Klopfsensoren kommt;
Verarbeiten des Signals (S), das von der Zahl der mit der Steuerungseinheit (16) verbundenen Klopfsensoren kommt, um die Klopfenergie (μ_i) jeder für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt betrachteten Verbrennung zu erhalten;
Filtern der Klopfenergie (μ_i) jeder für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt betrachteten Verbrennung;
Berechnen der mittleren Klopfenergie (μ_{i_m}) für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt mittels des gefilterten Wertes der Klopfenergie (μ_i) jeder für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt betrachteten Verbrennung;
Vergleichen der Klopfenergie (μ_i) jeder für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt betrachteten Verbrennung mit der mittleren Klopfenergie (μ_{i_m}) für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt;
dadurch gekennzeichnet, dass das Verfahren zusätzlich folgende Schritte beinhaltet:

Bestimmen der Varianz (σ_i) jeder für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt betrachteten Verbrennung in Abhängigkeit vom Vergleich zwischen der Klopfenergie (μ_i) jeder für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt betrachteten Verbrennung und der mittleren Klopfenergie (μ_{i_m}) für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt;
Berechnen der maximalen Varianz (σ_{i_max}) für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt mittels einer Rücknahme des im gegebenen Zylinder (2) verstellten Zündwinkels;
Vergleichen der maximalen Varianz (σ_{i_max}) für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt mit der Varianz (σ_i) jeder für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt betrachteten Verbrennung; und
Bestimmen der Entwicklung des Klopfvorgangs für jede für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt betrachtete Verbrennung in Abhängigkeit vom Vergleich zwischen der maximalen Varianz (σ_{i_max}) für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt und der Varianz (σ_i) jeder für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt betrachteten Verbrennung.

2. Verfahren nach Anspruch 1 und die weiteren Schritte beinhaltend:

Initialisieren, in einer vorläufigen Anpass- und Einrichtphase, eines ersten Kennfeldes ($MAPS_1$) mit den Werten der mittleren Klopfenergie (μ_{i_m}) für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt; und
Aktualisieren des ersten Kennfeldes ($MAPS_1$) mit dem gefilterten Wert der Klopfenergie (μ_i) jeder für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt betrachteten Verbrennung.

3. Verfahren nach Anspruch 2 und mit dem weiteren Schritt des Aktualisierens des ersten Kennfeldes ($MAPS_1$) mit dem gefilterten Wert der Klopfenergie (μ_i) jeder für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt betrachteten Verbrennung mittels eines gewichteten Mittelwertes zwischen dem gefilterten Wert der Klopfenergie (μ_i) jeder für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt betrachteten Verbrennung und dem Wert der mittleren Klopfenergie (μ_{i_m}) für einen gegebenen Zylinder (2) und in einem gegebenen, im ersten Kennfeld ($MAPS_1$) enthaltenen Maschinenbetriebspunkt.

4. Verfahren nach Anspruch 3 und die weiteren Schritte beinhaltend:

Initialisieren, in einer vorläufigen Anpass- und Einrichtphase, eines zweiten Kennfeldes ($MAPS_2$) von Zählern der für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt betrachteten Verbrennungen; und

Bestimmen der dem gefilterten Wert der Klopfenergie (μ_i) jeder für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt betrachteten Verbrennung und dem Wert der mittleren Klopfenergie (μ_{i_m}) für einen gegebenen Zylinder (2) und in einem gegebenen, im ersten Kennfeld ($MAPS_1$) enthaltenen Maschinenbetriebspunkt zuzuordnenden Gewichte in Abhängigkeit vom zweiten Kennfeld ($MAPS_2$) der Zähler der für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt betrachteten Verbrennungen.

5. Verfahren nach Anspruch 4, wobei der gefilterte Wert der Klopfenergie (μ_i) jeder für einen gegebenen Zylinder (2) betrachteten Verbrennung einen allmählich abnehmenden Wert hat.

6. Verfahren nach einem der vorangegangenen Ansprüche und die weiteren Schritte beinhaltend:

Initialisieren, in einer vorläufigen Anpass- und Einrichtphase, eines dritten Kennfeldes ($MAPS_3$) mit den Werten der maximalen Varianz (σ_{i_max}) für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt; und

Aktualisieren, während einer Lernphase, des dritten Kennfeldes ($MAPS_3$) mit der nominalen Geräuschspitze der i-ten, für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt betrachteten Verbrennung.

7. Verfahren nach Anspruch 6 und mit dem weiteren Schritt des Aktualisierens des dritten Kennfeldes ($MAPS_3$) mit dem nominalen Wert der Geräuschspitze der i-ten, für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt betrachteten Verbrennung mittels eines gewichteten Mittelwertes zwischen dem nominalen Wert der Geräuschspitze der i-ten, für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt betrachteten Verbrennung und dem Wert der maximalen Varianz (σ_{i_max}) für einen gegebenen Zylinder (2) und in einem gegebenen, im dritten Kennfeld ($MAPS_3$) enthaltenen Maschinenbetriebspunkt.

8. Verfahren nach Anspruch 7 und die weiteren Schritte beinhaltend:

Initialisieren, in einer vorläufigen Anpass- und Einrichtphase, eines vierten Kennfeldes ($MAPS_4$) von Zählern der für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt betrachteten Verbrennungen; und

Bestimmen der dem nominalen Wert der Geräuschspitze der i-ten, für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt betrachteten Verbrennung und dem Wert der maximalen Varianz (σ_{i_max}) für einen gegebenen Zylinder (2) und in einem gegebenen, im dritten Kennfeld ($MAPS_3$) enthaltenen Maschinenbetriebspunkt zuzuordnenden Gewichte in Abhängigkeit vom vierten Kennfeld ($MAPS_4$) der Zähler der für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt betrachteten Verbrennungen.

9. Verfahren nach Anspruch 8, wobei der nominale Wert der Geräuschspitze der i-ten, für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt betrachteten Verbrennung einen allmählich zunehmenden Wert hat.

10. Verfahren nach einem der Ansprüche 2 bis 9, wobei das erste Kennfeld ($MAPS_1$) und/oder das zweite Kennfeld ($MAPS_2$) und/oder das dritte Kennfeld ($MAPS_3$) und/oder das vierte Kennfeld ($MAPS_4$) eine Zahl von Zellen besitzen, die in Abhängigkeit von der Zahl (N_{cyl}) der Zylinder (2) und von den durch die Drehzahl (rpm) und durch die Last (load) gekennzeichneten Maschinenbetriebspunkten variiert.

11. Verfahren nach einem der vorangegangenen Ansprüche, wobei der Schritt des Berechnens der maximalen Varianz (σ_{i_max}) für einen gegebenen Zylinder (2) und in einem gegebenen Maschinenbetriebspunkt mittels einer Rücknahme des im gegebenen Zylinder (2) verstellten Zündwinkels durch Vermindern des im gegebenen Zylinder (2) verstellten Zündwinkels bis zu einem Wert, bei dem es zu keinem Klopfvorgang kommen wird, durchgeführt wird.

12. Elektronische Steuerungseinheit (16), die geeignet ist, ein Verfahren zum Erkennen der Entwicklung eines Klopfvorgangs in einer Brennkraftmaschine (1), ausgeführt nach einem oder mehr der Ansprüche 1 bis 11, zu realisieren.

Revendications

1. Procédé pour détecter le développement de phénomènes de détonation dans un moteur à combustion interne (1) muni d'un certain nombre de cylindres (2), d'une unité de commande (16), et d'un certain nombre de capteurs de détonation connectés à l'unité de commande (16) ; dans lequel des capteurs de détonation comprennent un accéléromètre et/ou un dispositif de mesure de tension qui est connecté au circuit électrique d'une bougie d'allumage (15), et disposé en série avec celui-ci, de façon à mesurer la tension aux bornes des électrodes de la bougie d'allumage (15) durant la combustion et/ou un dispositif de mesure de pression qui mesure l'oscillation de pression d'amplitude maximale (MAPO) de l'intensité des ondes de pression générées dans les cylindres (2) durant la combustion ; le procédé comprenant les étapes consistant à :

acquérir le signal (S) venant dudit nombre de capteurs de détonation connectés à l'unité de commande (16) ;
traiter le signal (S) venant dudit nombre de capteurs de détonation connectés à l'unité de commande (16) de façon à obtenir l'énergie de détonation (μ_i) de chaque combustion dont il est tenu compte pour un cylindre donné (2) et en un point de moteur donné ;
filtrer l'énergie de détonation (μ_i) de chaque combustion dont il est tenu compte pour un cylindre donné (2) et en un point de moteur donné ;
calculer l'énergie de détonation moyenne (μ_{i_m}) pour un cylindre donné (2) et en un point de moteur donné à l'aide de la valeur filtrée de l'énergie de détonation (μ_i) de chaque combustion dont il est tenu compte pour un cylindre donné (2) et en un point de moteur donné ;
comparer l'énergie de détonation (μ_i) de chaque combustion dont il est tenu compte pour un cylindre donné (2) et en un point de moteur donné à l'énergie de détonation moyenne (μ_{i_m}) pour un cylindre donné (2) et en un point de moteur donné ;
caractérisé en ce que le procédé comprend de plus les étapes consistant à :

déterminer l'écart (σ_i) de chaque combustion dont il est tenu compte pour un cylindre donné (2) et en un point de moteur donné en fonction de la comparaison entre l'énergie de détonation (μ_i) de chaque combustion dont il est tenu compte pour un cylindre donné (2) et en un point de moteur donné et l'énergie de détonation moyenne (μ_{i_m}) pour un cylindre donné (2) et en un point de moteur donné ;
calculer l'écart maximal (σ_{i_max}) pour un cylindre donné (2) et en un point de moteur donné à l'aide d'une réduction de l'avance à l'allumage activée dans le cylindre donné (2) ;
comparer l'écart maximal (σ_{i_max}) pour un cylindre donné (2) et en un point de moteur donné à l'écart (σ_i) de chaque combustion dont il est tenu compte pour un cylindre donné (2) et en un point de moteur donné ; et
déterminer le développement de phénomènes de détonation pour chaque combustion dont il est tenu compte pour un cylindre donné (2) et en un point de moteur donné en fonction de la comparaison entre l'écart maximal (σ_{i_max}) pour un cylindre donné (2) et en un point de moteur donné et l'écart (σ_i) de chaque combustion dont il est tenu compte pour un cylindre donné (2) et en un point de moteur donné.

2. Procédé selon la revendication 1, et comprenant les étapes additionnelles consistant à :

initialiser, dans une phase d'ajustement et d'établissement préliminaire, une première carte ($MAPS_1$) avec les valeurs de l'énergie de détonation moyenne (μ_{i_m}) pour un cylindre donné (2) et en un point de moteur donné ; et
remettre à jour la première carte ($MAPS_1$) avec la valeur filtrée de l'énergie de détonation (μ_i) de chaque combustion dont il est tenu compte pour un cylindre donné (2) et en un point de moteur donné.

3. Procédé selon la revendication 2, et comprenant l'étape additionnelle consistant à remettre à jour la première carte ($MAPS_1$) avec la valeur filtrée de l'énergie de détonation (μ_i) de chaque combustion dont il est tenu compte pour un cylindre donné (2) et en un point de moteur donné à l'aide d'une moyenne pondérée entre la valeur filtrée de l'énergie de détonation (μ_i) de chaque combustion dont il est tenu compte pour un cylindre donné (2) et en un point de moteur donné et la valeur de l'énergie de détonation moyenne (μ_{i_m}) pour un cylindre donné (2) et en un point de moteur donné contenues dans la première carte ($MAPS_1$).

4. Procédé selon la revendication 3, et comprenant les étapes additionnelles consistant à :

initialiser, dans une phase d'ajustement et d'établissement préliminaire, une deuxième carte ($MAPS_2$) de compteurs des combustions dont il est tenu compte pour un cylindre donné (2) et en un point de moteur donné ; et
déterminer les poids devant être attribués à la valeur filtrée de l'énergie de détonation (μ_i) de

chaque combustion dont il est tenu compte pour un cylindre donné (2) et en un point de moteur donné et à la valeur de l'énergie de détonation moyenne (μ_{i_m}) pour un cylindre donné (2) et en un point de moteur donné contenues dans la première carte ($MAPS_1$) en fonction de la deuxième carte ($MAPS_2$) de compteurs des combustions dont il est tenu compte pour un cylindre donné (2) et en un point de moteur donné.

5. Procédé selon la revendication 4, dans lequel la valeur filtrée de l'énergie de détonation (μ_i) de chaque combustion dont il est tenu compte pour un cylindre donné (2) a une valeur décroissant graduellement.

6. Procédé selon l'une quelconque des revendications précédentes, et comprenant les étapes additionnelles consistant à :

initialiser, dans une phase d'ajustement et d'établissement préliminaire, une troisième carte ($MAPS_3$) avec les valeurs de l'écart maximal (σ_{i_max}) pour un cylindre donné (2) et en un point de moteur donné ; et
remettre à jour, durant une phase d'apprentissage, la troisième carte ($MAPS_3$) avec la valeur nominale du pic de bruit de la $i^{ème}$ combustion dont il est tenu compte pour un cylindre donné (2) et en un point de moteur donné.

7. Procédé selon la revendication 6, et comprenant l'étape additionnelle de remise à jour de la troisième carte ($MAPS_3$) avec la valeur nominale du pic de bruit de la $i^{ème}$ combustion dont il est tenu compte pour un cylindre donné (2) et en un point de moteur donné à l'aide d'une moyenne pondérée entre la valeur nominale du pic de bruit de la $i^{ème}$ combustion dont il est tenu compte pour un cylindre donné (2) et en un point de moteur donné et la valeur de l'écart maximal (σ_{i_max}) pour un cylindre donné (2) et en un point de moteur donné contenues dans la troisième carte ($MAPS_3$).

8. Procédé selon la revendication 7, et comprenant les étapes additionnelles consistant à :

initialiser, dans une phase d'ajustement et d'établissement préliminaire, une quatrième carte ($MAPS_4$) de compteurs des combustions dont il est tenu compte pour un cylindre donné (2) et en un point de moteur donné ; et
déterminer les poids devant être attribués à la valeur nominale du pic de bruit de la $i^{ème}$ combustion dont il est tenu compte pour un cylindre donné (2) et en un point de moteur donné et à la valeur de l'écart maximal (σ_{i_max}) pour un cylindre donné (2) et en un point de moteur donné contenues dans la troisième carte ($MAPS_3$) en fonction de la quatrième carte ($MAPS_4$) de compteurs des combustions dont il est tenu compte pour un cylindre donné (2) et en un point de moteur donné.

9. Procédé selon la revendication 8, dans lequel la valeur nominale du pic de bruit de la $i^{ème}$ combustion dont il est tenu compte pour un cylindre donné (2) et en un point de moteur donné a une valeur croissant graduellement.

10. Procédé selon l'une quelconque des revendications 2 à 9, dans lequel la première carte ($MAPS_1$) et/ou la deuxième carte ($MAPS_2$) et/ou la troisième carte ($MAPS_3$) et/ou la quatrième carte ($MAPS_4$) ont un nombre de cellules qui varie en fonction du nombre (N_{cyl}) de cylindres (2) et des points de moteurs identifiés par le nombre de tours/minutes (t/min) et par la charge (charge).

11. Procédé selon l'une quelconque des revendications précédentes, dans lequel l'étape de calcul de l'écart maximal (σ_{i_max}) pour un cylindre donné (2) et en un point de moteur donné à l'aide d'une réduction de l'avance à l'allumage activée dans le cylindre donné (2) est effectuée par la dégradation de l'avance à l'allumage activée dans le cylindre donné (2) jusqu'à une valeur qui est telle qu'aucun phénomène de détonation ne se produise.

12. Unité de commande électronique (16), qui est appropriée pour mettre en oeuvre un procédé pour détecter le développement de phénomènes de détonation dans un moteur à combustion interne (1) mis en oeuvre selon l'une ou plusieurs des revendications 1 à 11.

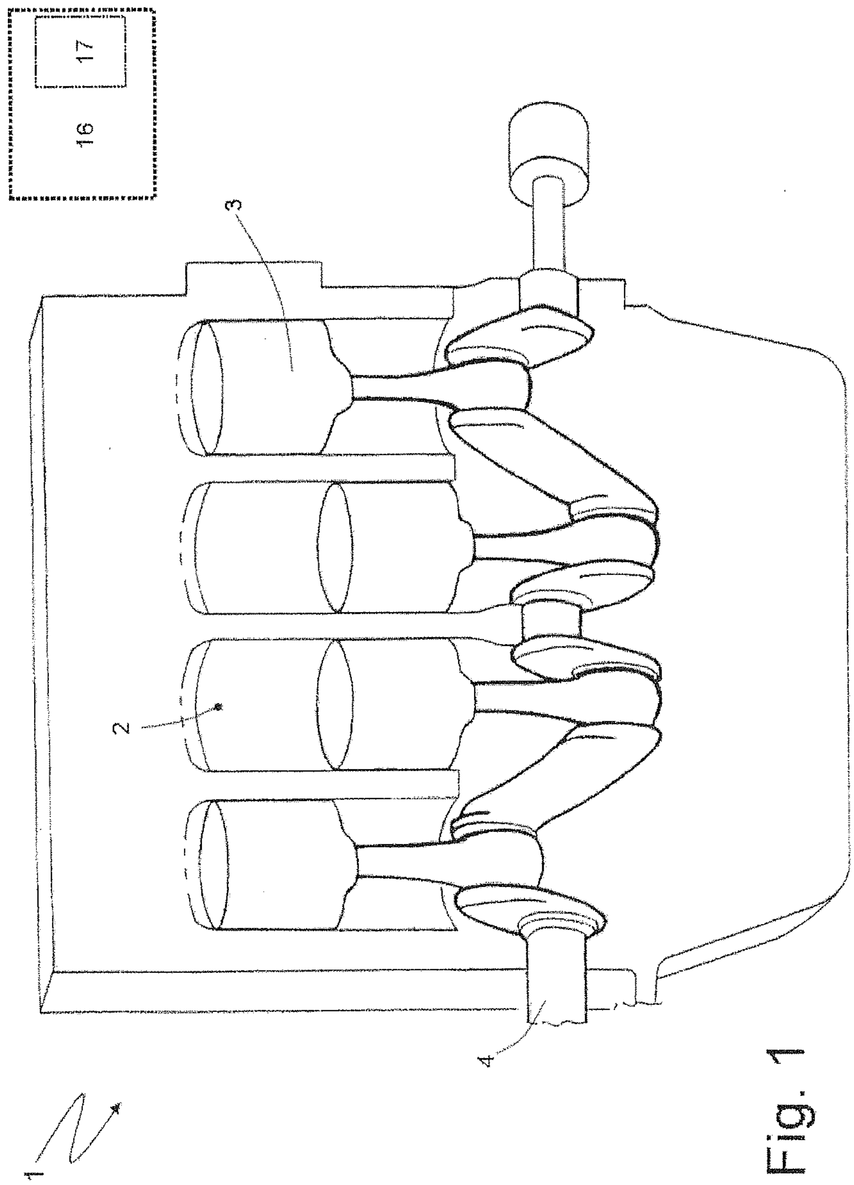

Fig. 1

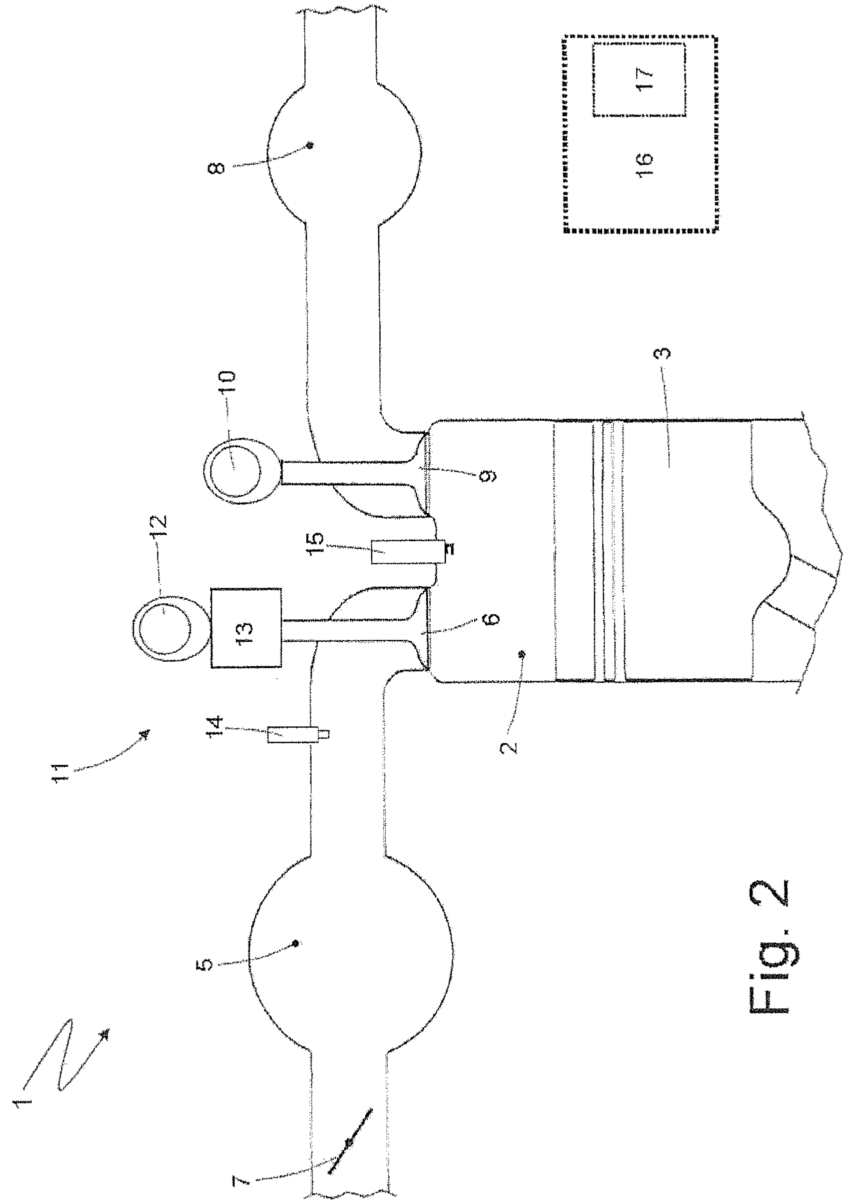

Fig. 2

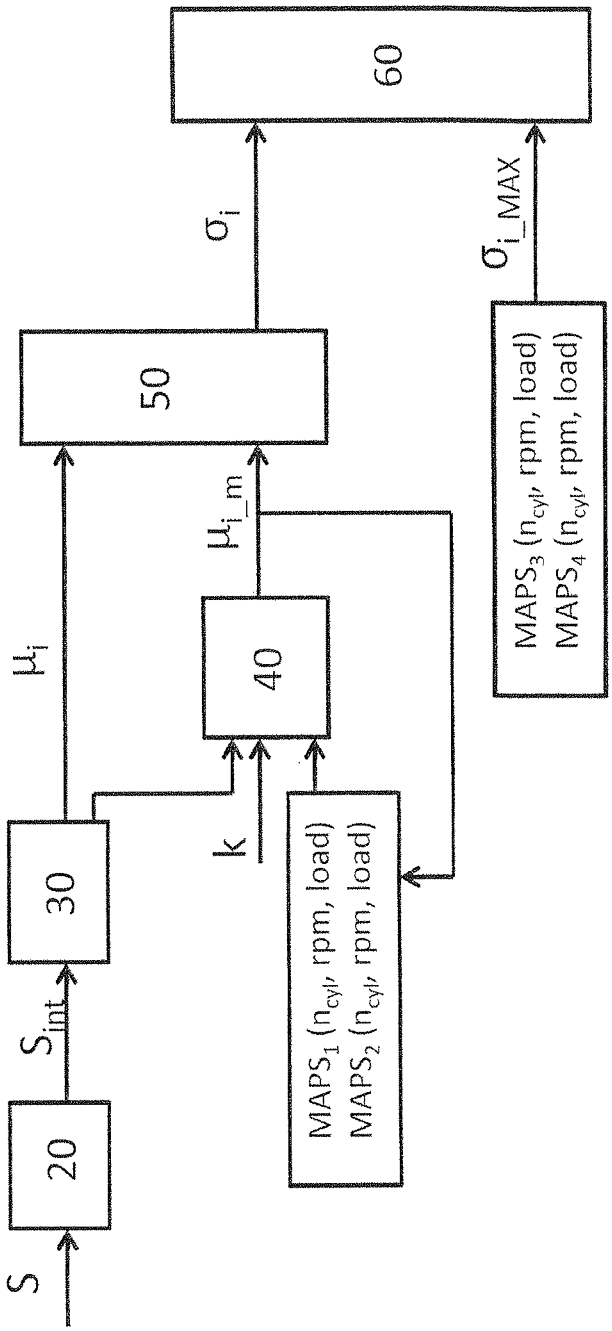
S
20
S_int
30
μ_i
k
40
μ_i_m
MAPS1 (n_cyl, rpm, load)
MAPS2 (n_cyl, rpm, load)
50
σ_i
60
σ_i_MAX
MAPS3 (n_cyl, rpm, load)
MAPS4 (n_cyl, rpm, load)

Fig. 3

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 5386772 A **[0007]**